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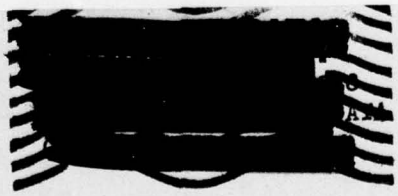
TECHNICAL REPORT

BIKINI SCIENTIFIC RESURVEY



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ANNEX IV

SUPPLEMENT TO VOLUME II

of the

BIKINI SCIENTIFIC RESURVEY

Report of the

TECHNICAL DIRECTOR

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This Annex contains the following supplementary ~~secret~~ pages which have been deleted from Volume II of the Bikini Scientific Resurvey Report. ~~These pages contain specific restricted data for which clearances are required in accordance with the Atomic Energy Act of 194~~

[redacted]

Section		Pages
*3.002	Submarine Geology at Bikini	41 -43
#3.004	Radiological Studies at Bikini	44
‡3.017	Radiochemical Analysis	1 -34
‡3.018	Soils Chemistry at Bikini	35 -40

* See p 10 of Volume II of Bikini Scientific Resurvey Report.

See p 22 of Volume II of Bikini Scientific Resurvey Report.

‡ See p 83 of Volume II of Bikini Scientific Resurvey Report.

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ILLUSTRATIONS

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3.017 Radiochemical Analyses

Radiochemical analyses were made in the Radiochemistry Laboratories in CHILTON (APA-38) as described in Section 2.006 of Volume I. The general purpose of these analyses was to investigate the presence and disposition of plutonium and fission products in a wide variety of samples taken from the Bikini area. More specifically, the analyses contributed to knowledge concerning the vertical and horizontal distribution of radioactivity in soils, sediments and rocks of the target area, and in addition, the distribution of such radioactivity in various minerals, sands, skeletons, waste products, and living organic forms.

The Radiochemistry Group was composed of two subgroups, as follows:

A. Plutonium Chemists: Dr. JACK SCHUBERT, Mr. D.P. AMES, and Mr. M.T. WALLING.

B. Fission Products Chemists: Dr. R.R. WILLIAMS, Dr. D.M. BLACK, Mr. R.R. EDWARDS, Mr. L.E. GLENDENIN, and Dr. W.H. HAMILL.

These two groups employed methods developed on the Plutonium Project to determine which elements were responsible for the radioactivity observed in the various samples. The low activities in large amounts of relatively inactive material required careful separations, using standard analytical gear to break down samples into their component elements and/or compounds. It was then possible to make gamma, beta, and alpha counts of known-magnitude samples in the Counter-Room.

Samples analyzed by the Radiochemistry Group were brought in from various localities in the Bikini area, and from target ships at Kwajalein. They included substances being studied by the Radiobiologists, the Experimental Biologists, and the Geologists. A good deal of the work, for example, was concerned with analysis of core samples obtained by the Submarine Geology Group from the bottom of Bikini Lagoon. In a sense, the Radiochemical analyses represented a service required by the members of several Scientific Groups. Results reported in the following pages are divided into a section on fission products and a section on plutonium.

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FISSION PRODUCTS

For the purpose of correlating the results of the fission-product survey, the relative activities and the radiation energies of the significant fission products to be expected at one year after the bomb explosion were calculated. The results of this calculation are presented in Table VII. Relative activities are given as percentages of the total activity. Fission products contributing less than 0.5% of the total activity are not included.

A. Tests made on core samples

1. Instrumentation and counting

The fission products were determined by beta counting with a Victoreen Geiger counter (alcohol-argon filled) and Tracerlab autoscaler circuit. All samples were counted on the top shelf of an aluminum sample holder housed in a shield built of lead bricks. The background of the counter was consistently 24 c/m. The geometry of the top shelf was determined accurately by counting weighed samples of U_3O_8 mounted in the same manner as the samples which were to be determined. Uncertainties due to back-scattering and self-scattering were largely eliminated by the geometry determination, since the U_3O_8 standards weighed approximately the same as the samples which were being measured. The absolute disintegration rate of UX_2 was taken as 620 d/m/mg of U_3O_8. The geometry of the top shelf for samples mounted on watch glasses was 24%, and for samples mounted directly on the mounting card the geometry was 19%. In some cases samples were deposited on platinum disks in which case the geometry was 22%.

2. Analytical procedures

Radiation analysis. Since the fission product picture at one year is relatively uncomplicated, it is possible to determine the major activities by analyzing the beta and gamma radiations from a gross sample of mud from the lagoon bottom. In fact, it developed that this was the most feasible method because of difficulties encountered in radiochemical analyses which are discussed later in the report. Absorption curves of the beta radiations from a sample of the mud showed that the chief component was the 3 Mev beta of Pr^{144} (daughter of 275d Ce^{144}). The

Radioisotope	Percentage of Total Activity	Radiation Energy (Mev)	
		Beta	Gamma
53d Sr^{89}	1.20	1.5	None
25y Sr^{90}	1.07	0.6	None
65h Y^{90}	1.07[b]	2.2	None
57d Y^{91}	2.50	1.6	None
65d Zr^{95}	7.38	0.4	0.8
35d Cb^{95}	7.38[b]	0.15	0.8
42d Ru^{103}	1.36	0.2	0.56
1.0y Ru^{106}	----[c]	---[c]	None
30s Rh^{106}	33.8[b]	3.9	0.3,0.8[a]
33y Cs^{137}	1.90	0.5,0.8	0.75
275d Ce^{144}	20.6	0.35	None
17.5m Pr^{144}	20.6[b]	3.1	0.2,1.25[a]
3.7y 61^{147}	6.04	0.2	None
2y Eu^{155}	0.81	0.2	0.084

Table VII. Relative fission-product activities at Baker Day plus one year.

[a]Low intensity

[b]Supported by the longer-lived parent

[c]The beta rays of Ru^{106} are so soft that they are practically undetectable and are not included in the calculations

only other hard beta present in the fission products at one year is the 3.9 Mev beta of Rh^{106} (daughter of 1.0y Ru^{106}). By counting through 90 mg/cm^2 of Al, 90% of the beta radiations of Pr^{144} and Ru^{106} are counted (as shown by absorption curves of chemically separated Ce^{144} and Ru^{106} samples), whereas no appreciable amount of the radiations from the other fission products are counted. The activity due to Rh^{106} was readily obtained by chemical separation of the parent Ru^{106} and subtracted from the total hard beta to obtain the activity of the Pr^{144}. In this manner the detailed distribution of Ce + Pr and Ru + Rh in Core No. 4 (target center) was obtained. Assuming that the distribution of Zr^{95} and Cb^{95}, and the other rare earths (61^{147} and Eu^{155}) was the same as for Ce, the theoretical distribution of these activities was then calculated relative to Ce from the data of Table VII. The value for Zr + Cb thus obtained was experimentally verified by gamma counting on some large samples ($\sim$0.5 g) of the mud. When the observed gamma activity, which at one year is practically entirely due to Zr + Cb (Cs^{137} is a significant gamma emitter at one year, but this isotope is not present in the mud), was corrected for a counting efficiency of 0.8%, good agreement with the theoretical value was obtained. The distribution of element 61 and Eu are expected to be identical with Ce because of the chemical similarity of the rare earths. The results of the complete analysis of the fission product distribution of Core No. 4 by the above method is presented below under No. 3.

Radiochemical analysis. Analyses for radioactive elements conformed as closely as possible to the procedures described in Clinton Laboratories Report CN-2815. Modifications were chiefly concerned with separation of the fission products from the mass of inactive materials present in the samples; secondarily, some special treatments of samples were performed in attempts to equilibrate the fission-product atoms with the inactive isotopic carriers for reasons discussed subsequently.

Core samples were dried at 110° C. before analysis, and generally ignited at 900° to 1,000° C for two hours, and dissolved in HNO_3 for analysis. Subsequent experiments indicated the ignition may not be necessary for good results, but ignited samples give clearer solutions than do those not ignited.

(a) Strontium. Strontium was separated from the HNO_3 solutions of core samples, along with some

calcium, by precipitation of the nitrate with fuming HNO_3. Separation from Ca was then effected by repeated extractions with 95% ethyl alcohol, which selectively dissolves the calcium nitrate. Final samples were prepared by precipitation of strontium oxalate from solutions of the nitrate. Conditions for the nitrate and oxalate precipitations are given in Clinton Laboratories Report CN-2815.

(b) Cesium. Cesium was separated from HCl solutions of the core samples by the procedure described in Clinton Laboratories Report CN-2815.

(c) Ruthenium. Solid core samples (ignited or unignited), or HNO_3 solutions of the samples, were placed in a distillation flask, and the separation of Ru was done as described in Clinton Laboratories Report CN-2815.

(d) Zirconium. Zirconium carrier was added to the HNO_3 solutions of core samples, and zirconium hydroxide precipitated by excess ammonium hydroxide. The hydroxide was reprecipitated twice (after dissolving in nitric acid) in order to effect a complete removal from Ca, which interferes in the next step of the procedure (Lanthanum fluoride precipitation). Then the procedure was carried out as described in Clinton Laboratories Report CN-2815, substituting for the cupferron precipitation a zirconium iodate precipitation from 8 M HNO_3; digestion of the precipitate for 30 min at 100° C results in a crystalline form which was filtered and dried by washing with alcohol and ether, weighed, and mounted for counting. (Standardization of the Zr carrier solution was performed by the same technique.)

(e) Cerium and trivalent rare earths. Cerium and Lanthanum carriers were added to HNO_3 solutions of the core samples, and precipitated as hydroxides by addition of excess ammonium hydroxide. The hydroxides were dissolved in HNO_3, and the resulting solution analyzed as described in Clinton Laboratories Report CN-2815.

3. Results

Gross activity in core samples. A large number of samples of the cores taken from the bottom of Bikini Lagoon were counted in order to determine the

horizontal and vertical distribution of radioactivity, as well as the total amount of fission-product activity in the bottom deposits. For gross activity determinations, a small amount of the core sample (averaging 30 mg) was deposited on a weighed watch glass (one-inch diameter), dried in the oven at 110° C, and reweighed to determine the dry weight of the sample. The watch glass containing the dried sample was then mounted on a card by covering with thin cellophane (3 mg/cm^2) and fastening with scotch tape. Counting was done with the sample on the top shelf at 24% geometry. The total absorption in the samples which includes self-absorption in the mounted material plus external absorption in the cellophane cover, air, and counter window, averaged 15 mg/cm^2.

The results of the gross activity determinations are presented in Table VIII. In order to obtain the absolute activity in disintegrations/minute/gram, it is necessary to multiply the observed activity in counts per minute by a factor of ten (obtained from the detailed analysis of core No. 4 discussed in the next paragraph) which corrects for geometry and the absorption of the beta radiations. The absolute activity is then divided by the value for one curie, 2.2 x 10^{12} d/m/g, to obtain curies/gram. Physical description of the core samples was supplied by Dr. R.D. RUSSELL.

Analysis of core samples. In order to obtain a complete picture of the distribution of the individual fission products, as well as the total activity in and on the lagoon bottom, a detailed analysis of Core No. 4 was carried out. The results of the radiation analysis of the core sample (described in A2 above) are plotted in figure 39. The curve for Zr + Cb is calculated relative to Ce from the theoretical ratio of Zr to Ce given in Table VII. The curve for element 61 + Eu is calculated relative to Ce from the data in Table VII. The curve for the total activity is simply the sum of the constituent activities.

Radiochemical analyses were carried out on various samples of Core No. 4, both for the purpose of checking the results shown in figure 39, and to determine the presence or absence of other fission products for which the radiation analysis method is not suitable.

Cesium and Sr analyses were carried out on several-gram portions of the mud, and no detectable activity above the background of the counter was obtained in

any case. The absence of these activities in the bottom deposits is to be expected, since Ce and Sr are soluble in sea water. The large concentration of Na and the appreciable concentration of Sr (13 mg/liter) in sea water would also tend to produce such a result.

The radiochemical analyses for Ru (see fig. 39) revealed two rather interesting facts: (a) the distribution of Ru in the mud layer of the core (first five feet) is quite different from that of the other elements, being more dependent on the depth in the core; (b) the total Ru activity in the mud is lower than expected (relative to Ce) by a factor of about ten. The low Ru value undoubtedly is due to the fact that fission-produced Ru is mainly in the form of a soluble anion and thus escapes in the sea water as in the case of Cs and Sr. The reason for the anamolous distribution of Ru in the core is not entirely clear, but this may be due to a difference in the mechanism of adsorption. The rare earths, Zr and Cb, are known to form colloids at trace concentrations, which adsorb fairly independently of particle size (as is borne out by the small slope of the curves in fig. 39), whereas Ru may be adsorbed by ionic exchange, in which case particle size is important as shown by the concentration of Ru in the top layer of the mud.

Radiochemical analysis for the trivalent rare earths (61, Eu, and Y) showed that at least 75% of the expected Y^{91} activity was missing from the mud on the basis of the $61^{147}+Eu^{155}$ activities present. This was determined by analysis of aluminum-absorption curves into the soft beta radiation of 61+Eu and the hard beta of Y^{91}. The low Y^{91} content of the mud very probably is due to the fact that this isotope has a 9.7 hr Sr parent which is soluble in sea water and whose half-life is long enough so that the mud stirred up by the bomb settled to the bottom before an appreciable amount of the Sr parent decayed. A settling time of a few hours is indicated by the Y^{91} value, and this is consistent with photographic data obtained.

Perhaps the most interesting and certainly the most perplexing aspect of the radiochemical analyses was the failure of the analyses for Zr, Cb, and the rare earths to recover the total activity of these elements known by beta and gamma counting rates and absorption curves of gross mud samples to be in the mud. The chemical analyses consistently recovered

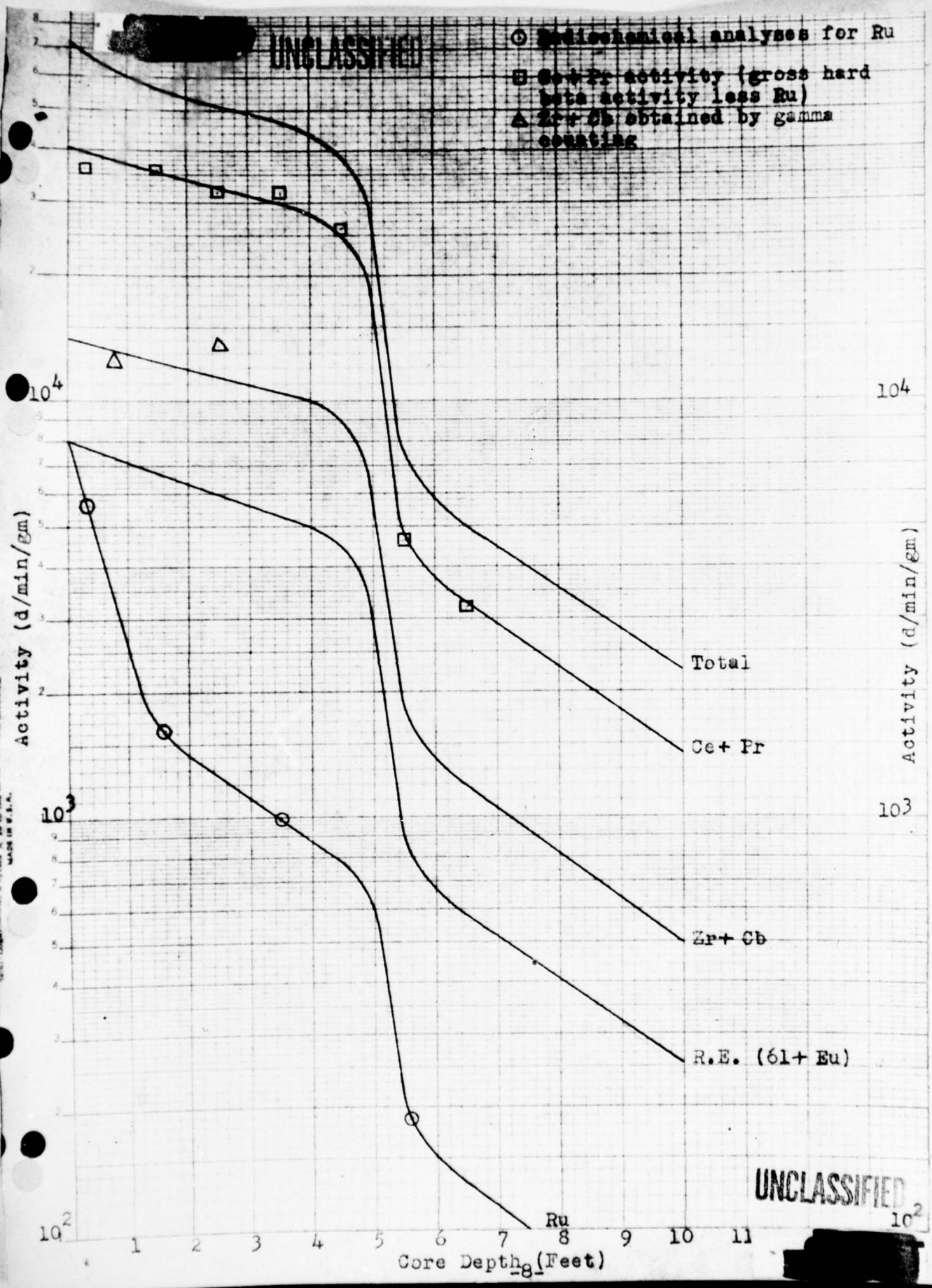

Figure 39. Distribution of fission products in Core No. 4.

only about 30% to 40% of the Zr, Ce, and trivalent rare earth activities present in samples of Core No. 4. Since the results of the chemical analyses were lower than expected, special attempts were made to bring the radioactive atoms into the same chemical state as the carriers. For this purpose, a portion of sample 1,225 (Core No. 4) was washed with water, dried at 110° C, pulverized, and mixed thoroughly. Samples of this material were then subjected to various severe chemical treatments in the presence of Ce and Zr carriers, and the resulting material analyzed for Ce and/or Zr.. The results of these experiments are shown in Table IX. A material balance experiment on the Ce analysis indicated that activity losses occurred chiefly in the supernatant liquid from the fluoride precipitation, and in the Zr iodate precipitation.

The failure to recover total activity by chemical analysis in spite of preliminary treatments of the mud including ignition, and fuming with various acids, oxidizing agents, and complexing agents has not been encountered before in radiochemical analyses of fission products, and it is possible that we are dealing with a new and highly refractory physical or chemical form of the fission products formed perhaps by the terrific heat and pressure of the bomb on the bottom material. The failure to achieve interchange between carrier and activity in perfectly clear solutions regardless of chemical treatment is a matter deserving further investigation.

In order to determine whether the amount of Ce activity recoverable by chemical analysis was constant throughout the lagoon bottom, Ce analyses were performed on HNO_3 solutions of three additional core samples. Determinations of Ru also were performed on the same samples, so that the percentage of the total cerium recovered could be calculated. Results of the analyses are given in Table X. The values given as "Total Ce" refer to the total hard beta activity, minus the value obtained for Ru.

Examination of Table X will show that the degree of recoverability of Ce activity is greater in cores that are some distance from the target center; more striking, however, is the correlation between the percentage recoverable and the gross specific activity of the sample. A possible explanation of these results can be based on the assumption that the non-recoverable atoms were those which were blasted directly, at high temperature, into the bottom material,

DISTRIBUTION OF GROSS FISSION PRODUCT ACTIVITY IN BOTTOM DEPOSITS

Core Number	Sample Number	Position Relative to Target Center	Depth Below Top of Core	Activity c/min/gm	Activity Curies/gm(x 10^8)	Description of Material
2	1,216	Target Center	0 ft-6 in	7,230	3.25	Soft mud (sandy, silty clay)
	1,217		½ ft-1 ft	3,900	1.75	"
	1,218		1 ft-2 ft	3,570	1.61	"
	1,219		2 ft-3 ft	3,170	1.43	"
	1,220		3 ft-4 ft	4,070	1.83	"
	1,221		4 ft-5 ft	3,940	1.77	"
						(Break at 5 ft 3 in)
	1,222		5 ft-7 ft	2,380	1.07	Sandy silt, coarser with depth
	1,223		7 ft-9 ft	346	0.16	"
4	1,224	Target Center	0 ft-6 in	6,500	2.92	Soft mud
	1,225		½ ft-1 ft	5,600	2.52	"
	1,226		1 ft-2 ft	5,500	2.47	"
	1,227		2 ft-3 ft	4,300	1.93	"
	1,228		3 ft-4 ft	4,350	1.96	"
	1,229		4 ft-5 ft	3,900	1.75	"
						(Break at 5 ft 3 in to:)
	1,230		5 ft-6 ft	670	0.30	Sandy silt, coarser with depth
	1,231		6 ft-7 ft	450	0.20	"
	1,232		7 ft-8 ft	177	0.08	"
	1,233		8 ft-9 ft	300	0.14	Muddy sand
	1,234		9 ft-10 ft	230	0.10	"
5	1,235	3,700 yd SW	0 in-2 in	161	0.07	Halimeda debris; green H., shells
	1,236		2 in-4 in	0	0	Finer H. debris
	1,237		4 in-10 in	0	0	H. debris, with mud
	1,238		10 in-16 in	0	0	"
	1,239		16 in-24 in	0	0	"
6	1,082	2,000 yd SW	0 in-1 in	722	0.32	Silty mud
	1,083		1 in-3 in	326	0.15	H. debris
	1,084		3 in-11 in	0	0	H. debris, with mud

Core Number	Sample Number	Position Relative to Target Center	Depth Below Top of Core	Activity c/min/gm	Curies/ gm(x 10^8)	Description of Material
7	1,085	1,000 yd SW	0 in-1 in	29,700	13.4	Silty mud
	1,086		1 in-7 in	3,380	1.52	H. debris
8	1,203	600 yd SW	0 in-5 in	42,000	18.9	Soft mud
	1,204		5 in-10 in	43,000	19.3	Soft silty mud
	1,205		10 in-15½in	1,500	0.68	Fine to coarse sand
	1,206		15½in-21 in	530	0.24	H. debris
9	1,207	300 yd SW	0 in-10 in	5,300	2.39	Silty mud
	1,208		10 in-15 in	2,300	1.07	"
	1,209		15 in-20 in	1,190	0.54	"
	1,210		20 in-23 in	755	0.34	Silt and fine sand
10	1,212	1,000 yd NE	0 in-1 in	73,000	32.8	Mud
	1,213		1 in-6 in	5,200	2.34	H. debris
	1,214		6 in-12 in	440	0.20	"
11	1,215	800 yd NNE	0 in-6 in	1,350	0.61	Thin layer mud; rest H. debris and sand
12	1,256	300 yd NW	0 in-4 in	17,200	7.74	Mud
	1,257		4½ in-10½in	504	0.23	Coarse H. debris
	1,258		11 in-14½in	690	0.31	Finer H. debris, coarse sand.
	1,259		14½in-18½in	415	0.19	H. debris, mud, sand
	1,260		18½in-22½in	73	0.03	"
13	1,261	300 yd WSW	0 in-1 in	23,000	10.7	Mud
	1,262		1 in-2 in	29,500	13.3	Mud, dark streaks
	1,263		2 in-6 in	20,700	9.3	"
	1,244		6 in-12 in	14,400	6.48	"
	1,245		12 in-16 in	16,800	7.56	"
	1,248		16 in-20 in	13,200	5.99	"
	1,252		21 in-24 in	600	0.27	Coarse H. debris
	1,253		24 in-25½in	750	0.34	H. debris, coral fragments, sand.

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Core Number	Sample Number	Position Relative to Target Center	Depth Below Top of Core	Activity c/min/gm	Activity Curies/gm(x 10^{8})	Description of Material
14	1,544	200 yd SE	0 in-6 in	6,270	2.82	Mud, dark streaks
	1,545		6 in-12 in	5,760	2.59	Mud
	1,546		1 ft-2 ft	6,300	2.84	"
	1,547		2 ft-3 ft	5,860	2.64	"
	1,548		3 ft-4 ft	6,220	2.80	"
	1,549		4 ft-5 ft	6,570	2.96	"
	1,550		5 ft-5 ft 3 in	4,750	2.14	"
	1,551		5 ft 3 in-5 ft 9 in	1,520	0.68	Silt
	1,552		5 ft 9 in-6 ft 5 in	890	0.40	Silt and fine sand
15	1,553	400 yd ESE	0 in-6 in	2,440	1.10	Trace of mud, remainder silty sand.
	1,554		6 in-12 in	1,350	0.61	Silty sand
	1,555		12 in-20 in	1,050	0.47	"
	1,556		20 in-21 in	--	--	H. debris
16	1,557	490 yd SSE	0 in-1/8 in	38,600	17.4	Mud
	1,558		1/8 in-6 in	7,270	3.27	Silty sand
	1,559		7½ in-13 in	480	0.22	Sandy H. debris
17	1,560	480 yd SbyW	0 in-1½ in	46,100	20.8	Mud, dark streaks
	1,561		1½ in-4 in	38,300	17.2	Mud
	1,562		4 in-12 in	690	0.31	Silty sand
	1,563		12 in-18 in	180	0.08	"
	1,564		18 in-22 in	23	0.01	"
	1,565		23 in-31 in	179	0.08	H. debris, some green H.
	1,566		31 in-42 in	1,470	0.66	"
	1,567		42½ in-44½ in	0	0	Muddy H. debris (original material).
18	1,568	475 yd SEbyE	0 in-1 in	45,300	20.4	Mud, dark streaks
	1,569		1 in-4 in	1,560	0.70	Silty sand
	1,570		5 in-11 in	610	0.27	H. debris and sand

Core Number	Sample Number	Position Relative to Target Center	Depth Below Top of Core	Activity c/min/gm	Activity Curies/ gm(x 10^8)	Description of Material
18	1,571	475 yd SEbyE	11 in-16½in	335	0.15	H. debris, green H.
	1,572		17 in-24 in	0	0	Muddy H. debris (original material).
	1,573		24 in-33 in	--	--	"
19	1,574	400 yd ENE	0 in-½ in	60,000	27.0	Mud
	1,575		½ in-1½in	4,380	1.97	Silt to coarse sand
	1,576		2 in-10 in	657	0.30	H. debris, green H.
	1,577		10 in-17 in	1,440	0.65	"
20	1,578	250 yd NEbyE	0 in-1½ in	46,500	20.9	Mud, dark streaks
	1,579		1½ in-6 in	10,200	4.59	Muddy silt
	1,580		6 in-12 in	820	0.37	Silt and fine sand
	1,581		12 in-20 in	206	0.09	Coarser silty sand
	1,582		20 in-22 in	538	0.24	H. debris, green H.
	1,583		22 in-26 in	1,010	0.45	H. debris
	1,584		26 in- 33in	--	--	"

Table VIIL

Sample	Treatment	% Ce Recovered	% Zr Recovered
1	Metathesis with 1 M H_2SO_4	37	35
2	"	----	40
3	HNO_3, H_2O_2	28	----
4	HNO_3, boiling	37	----
5	"	37	----
6	HF, $KBrO_3$, HNO_3, fuming	47	30

Table IX. Ce and Zr analyses on sample 1,225(Core No. 4 from bottom of Bikini Lagoon).

Core No.	Sample Number	Distance from Target Center	Total Activity (c/min/gm)	Total Ce (c/min/gm)	Ce Recovered by Analysis (c/min/gm)	% Ce Recovered
4.	1,225	0	5,600	4,500	1,750	39
7	1,085	1,000 yd	29,700	17,500	8,800	46
17	1,560	480 yd	46,100	31,000	19,100	62
19	1,574	400 yd	60,000	51,000	36,700	70

Table X. Ce analyses of various samples from the bottom of Bikini Lagoon.

whereas the recoverable fraction represents that which was adsorbed by the mud particles from the sea water following the blast. On this assumption, the particles which are most finely divided should have the highest specific activity (c/min/gm) since the smaller particles remained suspended for a longer period of time and presented a greater specific surface to the water, and thus contain more of the recoverable (adsorbed) activity. Furthermore, the fact that the fine particles remained suspended for a relatively long period of time explains the high specific activity values of samples at greater distances from target center. The fact that the non-recoverable Ce activity (in c/min/gm) also is somewhat lower in the high specific activity core samples seems to indicate that this form of the fission products is concentrated to some extent in the finest particles.

In line with these conclusions are three observations: (a) equilibration of a portion of sample 1,225 with aquaeous La carrier removed only 5% of the activity, whereas a portion of sample 1,085 yielded 25% of its activity in a similar experiment, indicating a much greater contribution of surface adsorbed activity; (b) ruthenium activity, which apparently is adsorbed by the mud rather than being irreversibly fixed in the mud (see fig. 39), is considerably higher in the shallow muds at some distance from the target center than in the target center mud; for example, the Ru activity in Core No. 4 is equal to about 10% of the Ce activity, whereas in the shallow muds Ru runs 20% to 40% of the Ce; (c) the activity in the shallow muds drops off quite rapidly with depth, indicating a dependence on particle size.

4. Discussion

From the distribution of fission products in Core No. 4 (fig. 39) and the physical description of the core (Table VIII), it is seen that the radioactivity is concentrated in the upper five feet of the core, which corresponds exactly to the thickness of the mud layer. A sharp drop in activity at about five feet is correlated with a change from mud to coarser material. Approximately 90% of the total core activity is contained in the mud, and this appears to be the case throughout the Bikini Lagoon bottom.

From Dr. R.D. RUSSELL'S data on mud depths obtained from coring, it is calculated that there are about half a million tons or 4.5×10^{11} gm of radioactive mud on the lagoon bottom, corresponding to 2.7×10^{11} gm dry weight. From the gross activity data of

Table VIII, it is calculated that the average specific activity of the entire mud deposit is four times the specific activity at the target center, which is taken as 2.2×10^8 curies per gm. The total fission-product activity in Bikini Lagoon bottom is therefore 2.4×10^4 curies.

B. Other fission products tests

The most prominent fission products present around Bikini Atoll one year after the underwater blast are shown in Table XI. The relative percentages of the fission products in the mud of Bikini Lagoon and the half-thickness values are approximate.

1. Radiobiological samples

The Radiobiology Group surveyed the distribution of gross fission-product activity in the tissues of a large variety of fish caught in the region in and around Bikini Lagoon. Their samples were mounted on steel plates or disks. The ashing of a weighed amount of wet tissue was done directly on the plate. A number of these mounted samples was loaned to the Radiochemistry Group, and absorption curves were constructed to characterize, qualitatively, the fission products present in a given tissue ash.

Study of the absorption curves shown in figures 40 and 41 lead to the conclusion that the soft tissues and bone of the fish have retained zirconium and columbium in preference to the other fission products, notably cerium. The concentration factor is at least of the order of 10 and probably more. No change in relative concentrations seems to have taken place in the algae, feces, or in the sponge.

It may be seen from figures 40 and 41 that a soft component of about 8 mg cm^{-2} half-thickness is observed in the liver, kidney, and bone of the fish tissues studied. This half thickness value lies between those of Zr and Cb. Since cerium is not held preferentially it is not expected that the low energy rare earth emitters would behave differently, inasmuch as they are very similar chemically. It is probable, therefore, that the observed half-thickness value of 8 mg cm^{-2} represents a mixture of Zr and Cb.

The amount of self-absorption in the mounted biological samples is not known precisely, because no weighings of the ashed residues were made. The self-absorption values in general ranged from about 25 mg

Radioisotope	Percentage of Total Activity in Mud[a]	Half-Thickness Value (mg cm^{-2})
Ce^{144}	75	190
Zr^{95}	2	12
Ru^{106}	20	250
61^{147} + Eu^{155}	5	5
Cb^{95}	0 0.5	3

[a] These results are based on gross activities measured with about 15 mg cm^{-2} total absorber.

Table XI. Relative percentages and half thickness values of the principal fission products at Baker Day plus one year.

cm^{-2} in the case of the bone sample (No. 936) to about 10 mg cm^{-2} for the soft tissue samples. About 4 mg cm^{-2} is allowed for the absorption equivalent of the air and counter window.

In order to confirm the selective retention of soft beta-emitting substances, the absorption curve of a thin mud sample (No. 1,203) was run. The total self-absorption was about 5 mg cm^{-2}. The half-thickness value was determined in detail in the region 5 mg cm^{-2} to 35 mg cm^{-2} (fig. 41), and was found to be 35 mg cm^{-2}. This result eliminates any doubt that the observed half-thickness of 8 mg cm^{-2} was due merely to a difference in self-absorption between the mounted biological samples and the mud and fecal samples.

The selective retention of Zr and Cb probably is due to two principal facts -- the colloidal nature of Zr and Cb, and their property of forming extremely insoluble phosphates. The colloidal nature of Zr and Cb would cause them to be retained by soft tissues through physical adsorption, and by the liver through that organ's known capacity to store colloidal matter of all kinds. The fractions of Zr and Cb which get into bone would remain, mainly because of the formation of insoluble phosphates.

Why cerium and the rare earths are not held in relatively larger amounts may be due to a greater degree of solubilization of these elements by the constituents of the bodily fluids of the fish. As a result, the excretion of cerium and the rare earths would be facilitated.

2. Edible products from Bikini Island

Samples of green pandanus fruit, edible tubers, green coconut "milk", and green coconut meat were ashed and gross counts were taken at approximately 10% geometry, with the following results:

Sample	c/min/gm
41 gm pandanus	0.6
36 gm tubers (Tacca: Taro root)	0.5
50 gm coconut juice	0.3
30 gm coconut meat	0.4

3. Sea urchins

Specimens were submitted for analysis by Dr. D.M.

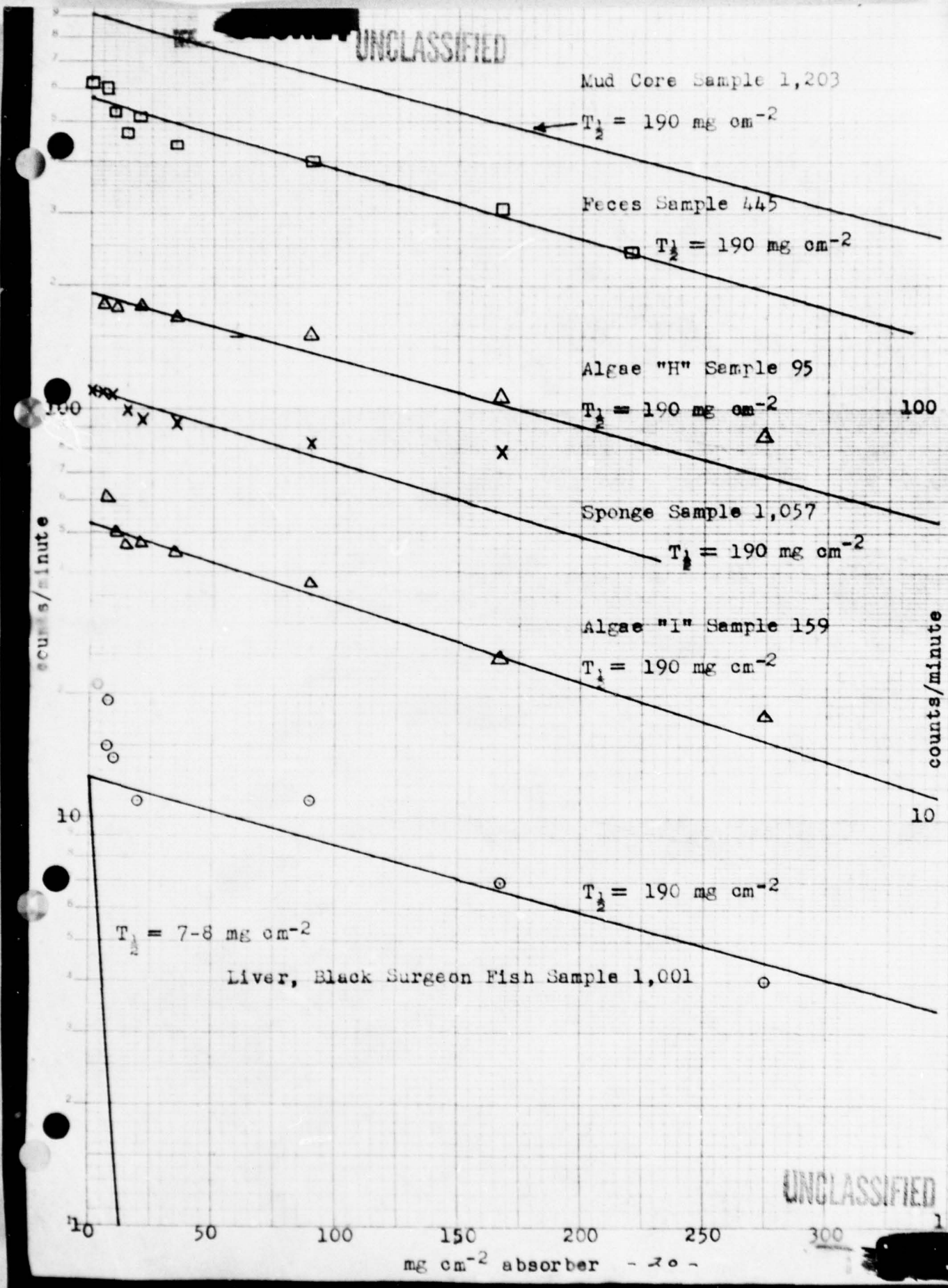


Figure 39. Absorption curves on the gross γ-activity of biological samples.

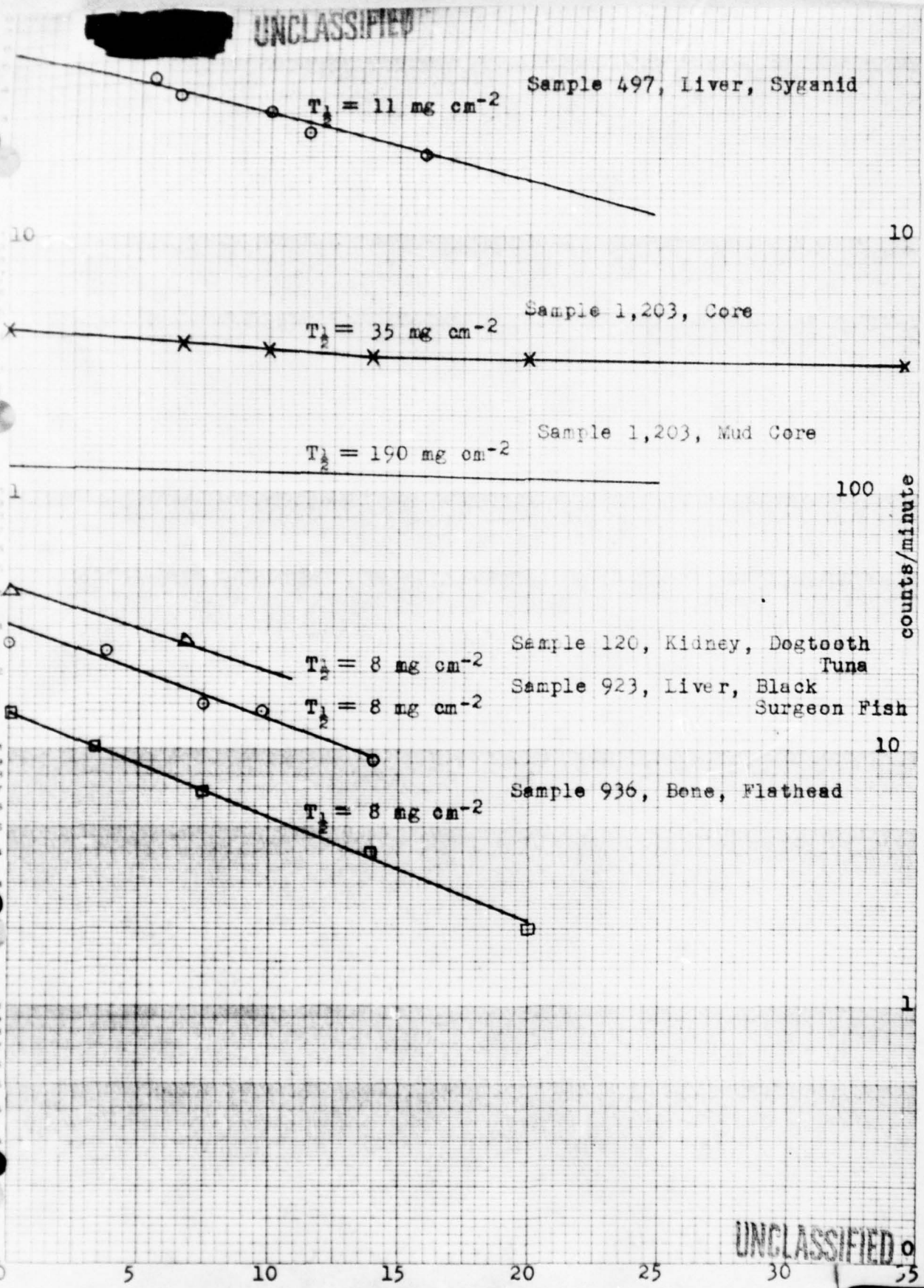


Figure ~~10~~ 41. Absorption curves of the gross activity of biological samples.

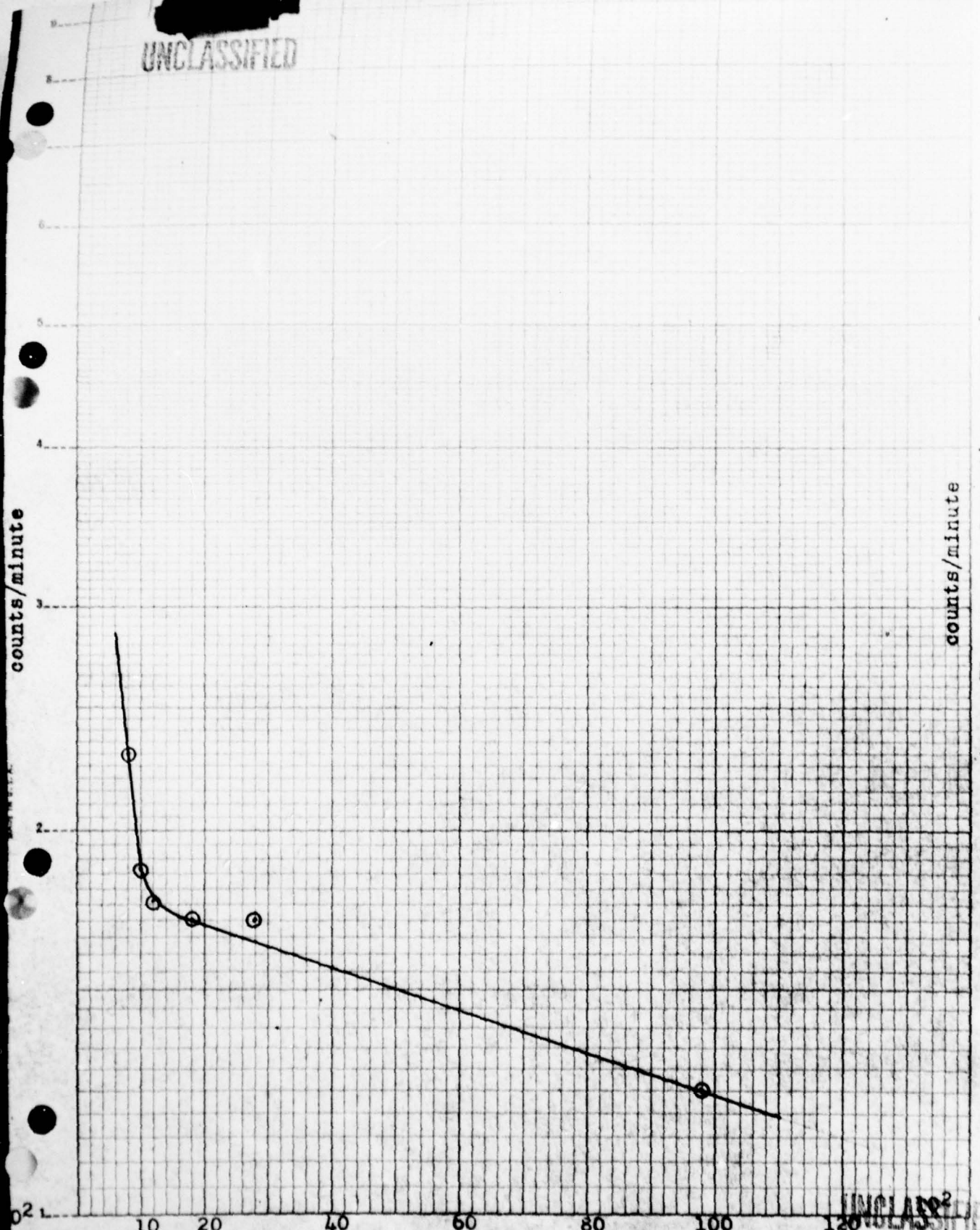


Figure 12. Gross absorption curve for sea urchin viscera sample.

counts/minute

mg cm^{-2}

WHITAKER. These animals were separated into two portions: the viscera, and the tests (outer, calcareous "shells"). The foregoing materials were ashed, dissolved, and 20 mg precipitated as ferric hydroxide. This precipitate, at 20% geometry, counted as follows:

Sample	c/min/gm
5 gm viscera	312
8 gm test	18

The whole viscera sample (as $Fe(OH)_3$) was dissolved in 10 ml of acid and aliquots taken for gross absorption curve and individual radioisotope analyses. Figure 42 shows the gross absorption curve obtained on 1 ml of this solution. There is evidence of an important weak beta component. Radioisotope analyses are given below; no chemical yields are available hence the results are qualitative:

Radioisotope	Aliquot	c/min	Estimated Chemical Yield	Added Absorber
Ru	2 ml	20	10 - 20%	90 mg cm^{-2}
Ce	2 ml	150	70%	90 mg cm^{-2}
Sr	1 ml	0	--	0
Zr	2 ml	0	--	0

Some other studies made at Bikini found that the Ce analysis give low results, so it appears that Ce-Pr and Ru-Rh account for the hard beta. Failure to find Zr was somewhat surprising, since there was considerable weak beta in the gross.

4. Halimeda

Halimeda was treated with acid to remove various surface growths and dissolve calcareous portions. Three types of material were then examined: (a) the undissolved cellulose, (b) acid-soluble material in a ferric hydroxide precipitate, and (c) solid material removed from the acid extract by filtration, with shredded paper added. (Affords opportunity for adsorption of trace materials in the acid solution.)

All samples were ashed, and small portions were taken for gross absorption curves. These curves are given in figure 43, and show no marked differences as to relative amounts of soft and hard betas. The soft beta is somewhat more than that expected if the activity were largely Ce-Pr, indicating that Zr may be concentrated slightly.

The three samples were analyzed for Ru-Rh, with

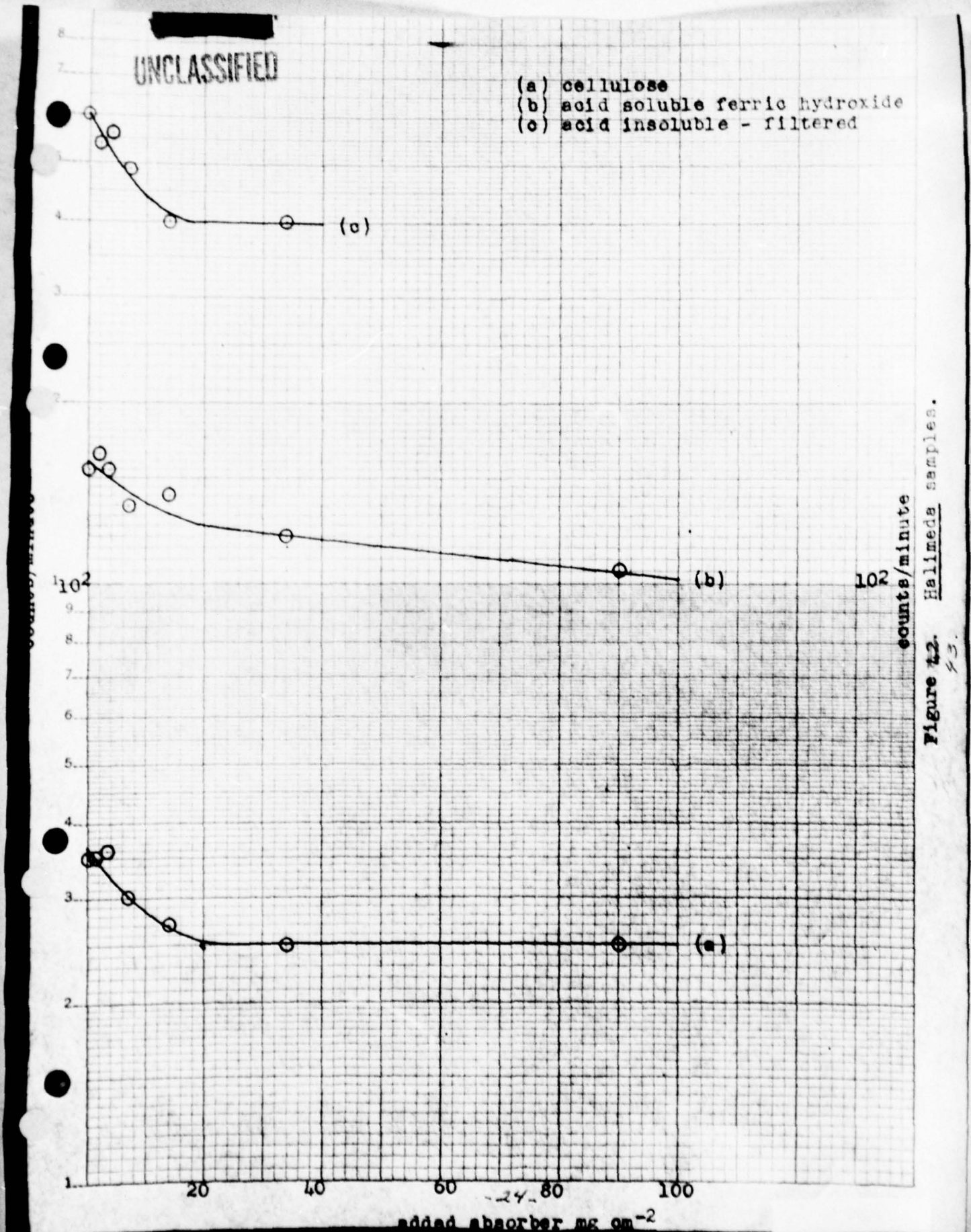


Figure 12. Halimeda samples.

counting done at 90 mg cm^{-2} added absorber. Samples (a) and (c) showed no detectable Ru-Rh counts from a gross of 75 c/min and 4,145 c/min respectively. Sample (b) showed 20% to 30% Ru-Rh activity. In each case it may be presumed that the remainder of the activity detected through 90 mg cm^{-2} of absorber is Ce-Pr.

5. Sand from spit midway between Bikini Island and Amen Island.

This sand gave a field reading of 10 to 15 times background, a condition which is general for the region. Sand samples were taken at the surface and at 1 ft, 2 ft, and 3 ft below the surface. Samples of 1 to 2 gm were ignited and dissolved, and aliquots evaporated for counting. Results were as follows:

Sample	Weight (mg)	c/min	c/min/gm
0 ft	42.4	0 ± 2	---
1 ft	35.3	9 ± 2	250 approx.
2 ft	42.1	0 ± 2	---
3 ft	75.0	6 ± 2	80 approx.

In order to achieve further sensitivity, a 21-gram sample from the surface was ignited and dissolved. A few mg of ferric hydroxide were precipitated with a few drops of Zr, Ce, and Ru carriers to ensure co-precipitation. This precipitate (10 mg to 20 mg) was mounted and an absorption curve taken (fig. 44). Analysis of absorption curves indicates chiefly Ce. A Ru analysis was performed on the whole sample and gave no Ru-Rh activity. For this comparison the counts were taken at 90 mg cm^{-2} added absorber.

gross (90 mg cm^{-2})	1,036 c/min
Ru-Rh (90 mg cm^{-2})	1 ± 2 c/min

6. Tar deposit on rocks from sand spit northwest of Bikini Island

Field tests showed that some patches of tar were more radioactive than any other specimens examined between Bikini Island and Amen Island. Different specimens of tar gave widely different readings. A small sample, believed to be representative of the more active deposits, was taken for detailed analysis. The tar was dissolved in carbon tetrachloride and the residual sand washed repeatedly with carbon tetrachloride. The extracts were combined and evaporated to dryness at

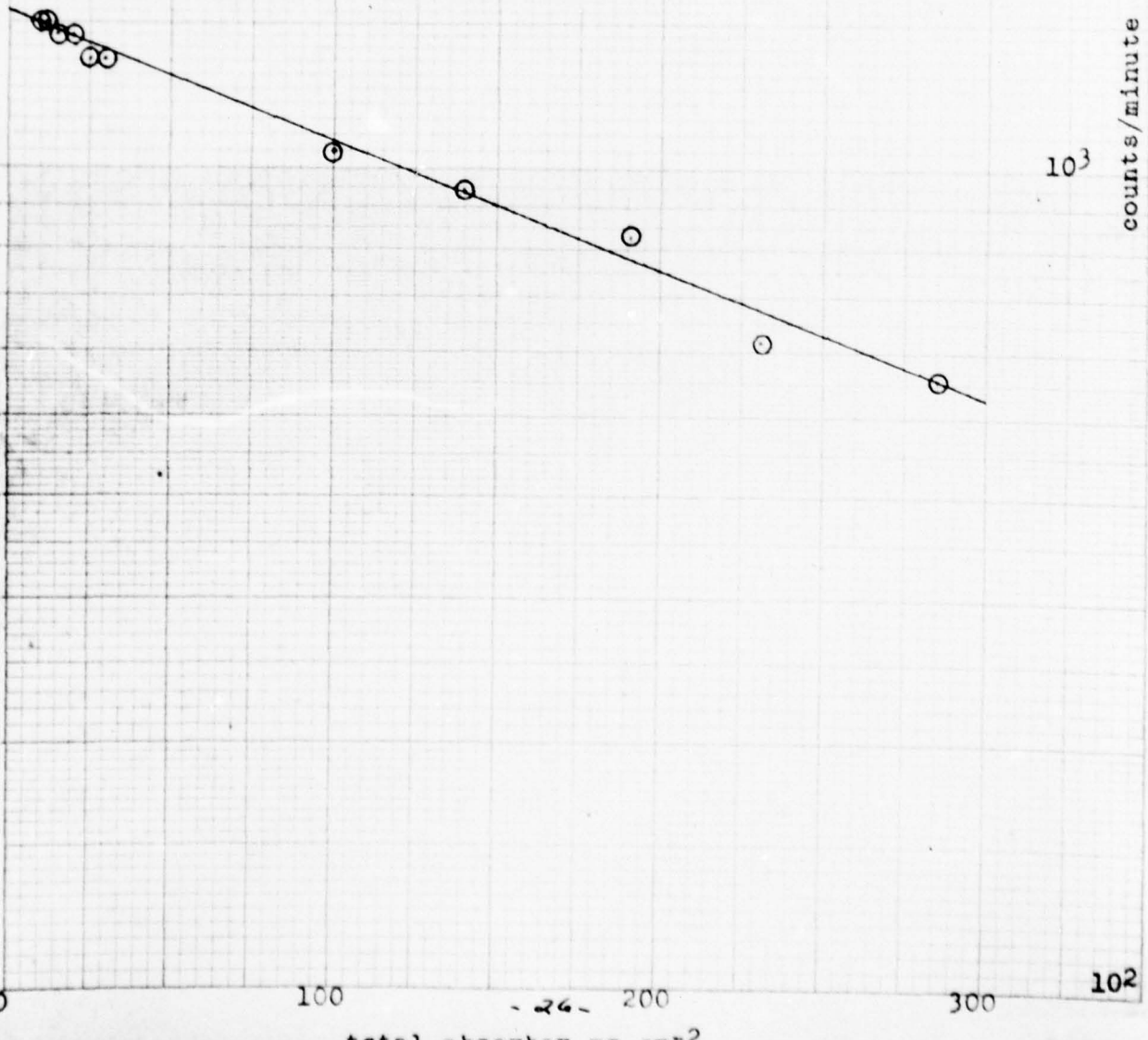


Figure 2. Gross absorption curve for sand, midway between Bikini Island and Amen Island.

100° C. The tar was ignited and the ash dissolved in HNO_3; aliquots of this solution were counted for alpha, gross beta, Sr, Ce and Ru. Results were as follows:

Sample	Weight in gm.	c/min/gm	Elements
sand	0.065	1.7×10^4	gross beta
ash	0.00087	3.6×10^5	gross beta
ash	0.0087	2.7×10^5*	Ce-Pr
ash	0.0087	6.2×10^4	Ru-Rh
ash	0.0435	2.3×10^3	Sr

* Observed count at 140 mg cm^{-2} absorber, which includes one-half of Pr betas, and no Ce betas. Two and one-half times the observed count gives the total for Ce and Pr.

7. Koa Water

Measurements of total fission-product activity in water from Bikini Lagoon were made on scavenger precipitates (ferric hydroxide), and no samples with activity distinctly above background were obtained. The precipitate from 20 liters of water contained no detectable activity, indicating a gross activity of less than 10^{-12} curies per liter.

8. Materials taken from target fleet

Samples from FALLON (close to Test -B target center) and WAINWRIGHT (far from Test -B target center) were obtained at Kwajalein, for purposes of determining the Sr^{89} to Sr^{90} ratio at different distances from the blast center. From the known fission yields and half-lives of these and parent radioisotopes, the anticipated ratio of Sr^{89} to Sr^{90} at Baker Day plus 13 months would be almost exactly one.

The 89 and 90 fission-product chains have the following members:

$$Kr^{89} \xrightarrow[\text{beta-}]{2.6\ m} Sr^{89} \xrightarrow[\text{beta-, 1.5 Mev}]{55\ d} Y^{89}\ \text{(stable)}$$

$$Kr^{90} \xrightarrow[\text{beta-}]{33s} Sr^{90} \xrightarrow[\text{beta-, 0.6 Mev}]{25\ y} Y^{90} \xrightarrow[\text{beta-, 2.2 Mev}]{65\ h}$$

Because of the relatively slow decay of the parent gas Kr^{89}, it is to be expected that a larger fraction of the 89 fission chain will escape from a base surge, such as the one formed in Test B. Therefore, the Sr^{89} to Sr^{90} ratio might well be less than that predicted above.

[redacted]

The isolation of Sr consisted of three successive strontium nitrate precipitations, three ferric hydroxide scavengings, and a final strontium chromate precipitate which was dried with alcohol and ether and weighed. The absorption curve obtained immediately after isolation of the FALLON sample is shown in figure 5. The observed ratio of Sr^{89} to Sr^{90} was 0.55. The WAINWRIGHT sample was not sufficiently active to provide a good absorption curve.

In order to test the purity of the Sr activity, the two precipitates were re-dissolved in acid and the oxalate precipitated, dried, weighed, and counted at 0 absorber and 90 mg cm^{-2}. Specific activities (c/min/gm) obtained were:

Absorber (in mg cm^{-2})	FALLON		WAINWRIGHT	
	1st ppt.	2nd ppt.	1st ppt.	2nd ppt.
0	47	58	3.0	3.06
90	11	12	1.06	0.65

The only significant change produced by the second precipitation was that noted at 90 mg cm^{-2} for the WAINWRIGHT sample, which suggests that some Cs contamination may have been present in the first precipitate. From comparison of the specific activities of the two samples (second precipitate) at 0 and 90 mg cm^{-2} added absorber, it is apparent that the ratio of hard to soft beta is about the same in the two samples.

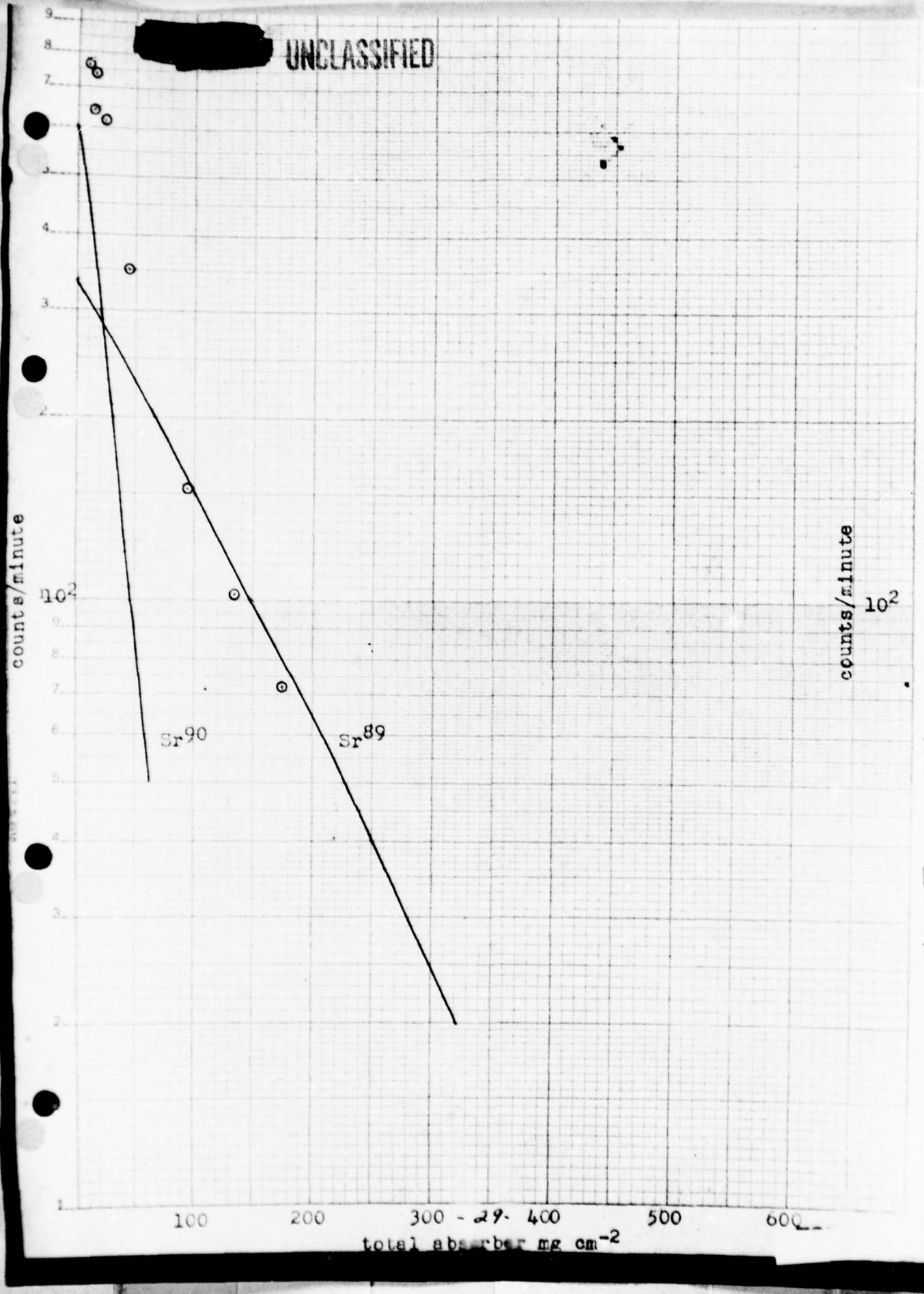
The activity growth of the two samples was observed through 90 mg cm^{-2} absorber, to determine the growth of 65 hr Y^{90}, with the following results:

	0 Days	3 Days
FALLON	125 c/min	336 c/min
WAINWRIGHT	12 c/min	33 c/min

The foregoing figures confirm the preceding result that the Sr^{89} to Sr^{90} ratio is approximately the same in the two samples. The activity growth at 90 mg cm^{-2} added absorber indicates that there is less Sr^{89} than Sr^{90} when due allowance is made for the difference in absorption of Sr^{89} and Y^{90}.

The correction factor for the weaker beta (Sr^{89}) will be about 1.33 at 90 mg cm^{-2}.

	0 Time (Sr^{89})	Growth (Zr^{90})
Sr, FALLON	125 c/min	211 c/min
Computed	[redacted]	211 c/min



counts/minute
10^2

Figure 2. Strontium beta absorption curve from FALLON sample.

Furthermore, in three days the growth of Y^{90} is only about 60% complete. The foregoing calculation gives a ratio of Sr^{89} to Sr^{90} approximately equal to 0.5, in fair agreement with the previous determination.

PLUTONIUM

A. Plutonium content of core samples

Table XII lists Pu assays on several core samples made both by analyses (using the cupferron extraction method) and by direct alpha counting of a thin mud deposit. It was found that the chemical analyses were erratic, varying from 50% to 150% of the value obtained by direct counting. Direct product activity in several different cores.

B. Other plutonium analyses

Biological materials assayed included vegetation from Bikini Island, and the organs of several fish species. Mounted samples of ashed fish tissue were provided by the Radiobiology Group. Those on which residue was small were counted directly, while others were assayed by chemical analysis. The absorption thicknesses of the samples probably were no higher than 5 mg cm^{-2}.

The actual weight of the ash has not been determined.

1. Instrumentation and counting

Alpha counting was done with a parallel plate counter and scale of eight circuit. This instrument is of a standard type manufactured by the instrument section of the Argonne National Laboratory, Chicago, Illinois. The geometry was about 50%, and a specific activity of 68,000 c/min/microgram of Pu was used in the calculations.

2. Analytical procedures

All samples were ashed in order to remove organic matter. In some instances samples of biological material were wet ashed by alternate treatments with

Sample Number	Location Relative to Target Center	Dry Weight of Sample (gm)	Method of Analysis	Grams Pu per gm Sample ($\times 10^{10}$)
1,224	Target Center	3.88	Cupferron	3.3
1,228	" "	3.16	"	4.4
1,230	" "	3.60	"	0.6
1,226	" "	5.003	"	9.2
1,227	" "	5.002	"	5.0
1,207	300 yd SW	5.004	"	5.3
1,256	300 yd WNW	5.003	"	4.9
1,203	600 yd SW	5.063	"	66.3
1,203	600 yd SW	9.6×10^{-3}	Direct Counting	72.5
1,212	1000 yd NE	4.6×10^{-3}	Direct Counting	128.8
1,560	480 yd SbyW	13 mg	Direct Counting	42.3
1,568	475 yd SEbyE	9.3 mg	Direct Counting	60.0
1,574	400 yd ENE	4.7 mg	Direct Counting	60.6

Table XII. Plutonium content of core samples.

fuming HNO_3 and 30% hydrogen peroxide until the ash was white (MUC-Hg-1,217, p7 describes wet-ashing procedure in detail). After ashing the residue was completely soluble in HNO_3 or HCl. When a sample contained very little solid matter after ashing, the acid solution was transferred directly to a Pt dish, dried, flamed, and counted.

When the acid solution contained very little Ca but considerable residue, the Pu could be advantageously carried by a lanthanum fluoride precipitate. The method used is described in Manhattan Project Report, CL-DEK-1. Solutions high in Ca content were most rapidly analyzed by the cupferron procedure. The method is detailed in Manhattan Project Reports CN-2,204, p.5 and MUC-TOJ-33, p.19. Complete recovery by this method was not achieved, hence parallel blank runs with known amounts of Pu tracer were made. The average of ten recovery runs was 53±3%. The absolute accuracy of the cupferron, as checked by direct counting measurements, was quite satisfactory.

3. Results

Table XIII lists the Pu content of biological materials analyzed. Apparently vegetation on Bikini Island, algae, and fish did not contain any significant amounts of Pu. The amount of Pu in relationship to fission products was less than might be expected. In fish tissues this result could be due to high retention of Zr and Co. It seems reasonable to assume that in the case of fish, metabolic behavior of Ce and Pu are similar.

Examination of Table XIV will show that sea water was practically free of Pu. Similarly, urine from a wild dog captured on Bikini Island (Plutonia) indicated that the animal probably had less than 0.1 micrograms of Pu fixed in her body. The black material from core sample No. 1,263 appeared to be a carbon-rich substance derived from petroleum. Its radioactive content, while less than that of the core itself, exhibited the same distribution of fission products found in mud.

Under the adverse conditions of alpha counting which existed, it was not possible to take counts long enough to reduce statistical error appreciably. Under good operating conditions the counter background was about two disintegrations per minute. Four disintegrations per minute above background, or 0.3 x 10^{-10} gm of Pu, could be detected with reasonable certainty.

PLUTONIUM CONTENT OF BIOLOGICAL MATERIALS

Sample Number	Source	Organism	Tissue Assayed	Method of Analysis	Grams Pu Per Gm Wet Tissue (x 10-11)
1,026 1,025	Ion Island	Yellow-Lined Squirrel Fish	Gills Bone	Direct Deposit Cupferron	3.6±0.8
1,000 996	Ion Island	Black Surgeon Fish	Feces Bone	Cupferron "	3.6±0.6 -----
991 989 988	Ion Island	Spotted Grouper	Muscle Gills Bone	Direct Deposit Cupferron "	----- ----- -----
941	Coral Head 1,709	Flathead	Liver	Cupferron	16±3
920 919	Coral Head 1,709	Black Surgeon Fish	--- Gills	--- Cupferron	----- 27±3
916 911	Coral Head 1,709	Red Squirrel Fish	Spleen Gills	Direct Deposit "	----- 2.4±0.4
498 497 494	Chilton Anchorage	Syganid	Kidney Liver Skin	Direct Deposit " "	0.44±0.3 7.4 2.9±0.3
445 444	Coral Head 2,007	Goat Fish	Feces Gills	Direct Deposit "	----- -----
173 172 167	Coral Head 1,709	Grouper Fish	Testes Liver Bone	Direct Deposit " "	----- ----- 0.57±0.3
120 117	500 yd astern Chilton Anchorage	Dogtooth Tuna	Kidney Gills	Direct Deposit "	0.52±0.2 -----
95	-----	Algae "H"	Entire	Direct Deposit	-----
	North End Bikini Island	Tuber Pandamus Corn Green Coconut	Entire " "	Direct Deposit " "	----- ----- -----

Table XIII.

Sample	Amount	Method of Analysis	Grams Pu per gm
Urine sample from Plutonia*	260 ml	Wet Ash Cupferron	--
Black material from core 1, 263**	0.178 gm	Wet Ash Direct Deposit	1.6×10^{-10}
Sea water from bow of Chilton	20 l	Ferric hydroxide scavanger followed by lanthanum fluoride	10^{-14} (upper limit)

* No beta or gamma activity above the background was detected.

** A total of about 3,900 beta counts per mi/gm was observed when the total self absorption was 7 mg cm^{-2}.

Table XIV. Plutonium content of miscellaneous samples.

3.018 Soils Chemistry at Bikini

The soil chemistry studies were concerned only with the lagoon bottom sediment obtained by coring in the Test B target area. This material was obtained from the Submarine Geology Group, and was tested in the Radiochemistry Laboratory by Mr. L. F. SEATZ.

The first studies were made in an attempt to determine how the radioactive materials were held by the mud particles. It was surmised that the radioactive materials were adsorbed on the finer mud particles by cation exchange. This process is the means by which most cations are held in soils by the alumina-silicate colloidal material. The cation exchange capacity of a series of samples from Core No. 4, taken at the target area center, was determined by the ammonium acetate method as described in U. S. Department of Agriculture Circ. No. 757, pg. 8-10, with slight modifications. The results showed that the surface foot of mud had a cation exchange capacity of 0.5 milliequivalents per 100.0 gm mud (dry weight), whereas, the remaining 8 feet of core showed a zero exchange capacity. It is believed this slight amount of exchange can be attributed to the small amount of organic matter present in the surface foot. Since the mud is practically pure calcium carbonate, few free valence bonds of the type which give rise to cation exchange capacity in alumina-silicate minerals would be expected to be present.

The ammonium acetate leachate was boiled to dryness, taken up with concentrated nitric and hydrochloric acids, boiled to dryness again, and finally taken up with 0.1 N nitric acid. An aliquot was evaporated to dryness on a watch glass and gross beta counts taken. Approximately 2% of the gross beta count was removed by the ammonium acetate leaching. An absorption curve taken on this material revealed that the major portion of the radioactive substance was cerium, with a small zirconium component.

Since it was evident that the radioactive materials were not held by normal base exchange, another approach was made to the problem. Dr. JACK SCHUBERT of the Radiochemistry Group has done considerable work with the radio elements and states that at the pH of sea water, the rare earths cerium, plutonium, columbium and zirconium would behave mainly as radio colloids. As such, these elements would be adsorbed to the finer mud particles and held in this manner. In order to remove the radio element from such a colloidal complex it would be necessary to form soluble complexes with

Figure 46. Radiochemists working in the counter-room on CHILTON (APA-38). Left to right: Mr. D.P. AMES, Mr. M.T. MAILING, Dr. JACK SCHUBERT, Mr. L.F. SEATZ, and Dr. R. WILLIAMS. ABCR Photo No. 5090-4.

Figure 47. Mr. W.H. HAMMILL performing a fission-product analysis in the Radiochemistry Laboratory aboard CHILTON (APA-38). ABCR Photo No. 5090-10.

the radio element which would allow the element to go into solution. Zirconium, columbium, and plutonium are more easily complexed as oxalates. Cerium, and most of the other radio elements, are more easily complexed into soluble citrates.

A study was undertaken to determine the effects of various complexing agents on the removal of radio elements from the lagoon mud. The 6-inch sample from Core No. 2 at the target area center was used. Solutions employed were 0.1 N $LaCl_3$ made slightly acid; 0.1 N tartaric acid; 0.1 N phosphoric acid; water, and a 2% solution of methylene blue. All of the acid solutions were brought to pH 7.0 with concentrated NH_4OH. The mud was oven dried at 110° C overnight, and crushed gently in a mortar with a wooden pestle. One gram samples were weighed into 15 ml centrifuge tubes and 10 ml of one of the above solutions added. The tubes were shaken periodically for 30 min and then centrifuged. One ml of the supernate was evaporated on a watch glass and the beta activity determined. The results are shown in Table XV.

Absorption curves were run on several of the above solutions, and they tended to substantiate the foregoing statements. The citrate solution removed cerium for the most part. The amount removed by citrate compares favorably with the amount of cerium present, as determined by the Radiochemists. The absorption curve for oxalate shows that most of the activity removed was due to zirconium and columbium. Lanthanum also seems to remove cerium.

Since the process of adsorption is a function of the amount of surface exposed, it was thought advisable to determine the particle size distribution in samples from Core No. 2 taken at the target area center. The procedure was as follows:

A 10 gm sample of the dry material was added to 250 ml of water and 10 ml 1.0 N sodium metaphosphate was added as a dispersing agent. This suspension was mixed in a Stevens Blender for 30 min. The suspension was then transferred to a liter graduated cylinder, made to the mark with water, and shaken several times. At the end of 3 min 45 sec, a 20 ml sample was removed from a depth of 10 cm. This sample represented the silt plus clay fractions (less than 20.0 microns). At the end of 6 hr 30 min, another 20 ml sample was removed from a depth of 10 cm. This sample represented the clay fraction (less than 2.0 microns). The particle size distribution in the various samples is shown in Table XVI.

The data in Table XVI show that the percent of fine material decreases with depth, as would be expected. The larger amount of fine material at the surface also means a larger amount of surface area exposed, and therefore, a greater potentiality for adsorption.

Solution	counts/min/gr	% gross activity
$LaCl_3$	725	10
Tartrate	884	12
Citrate	2,000	28
Oxalate	725	10
Acetate	402	5.6
Phosphate	515	7.1
Water	290	4.0
Methylene blue	242	3.4

Table XV.

Depth	% Silt (20-2.0 microns)	% Clay (<2.0 microns)	% Water
6-12 in	34.3	41.3	76.4
24-36 "	38.5	41.0	66.5
48-60 "	26.0	40.5	65.0
84-108 "	14.0	37.5	55.0

Table XVI. Particle size distribution in various mud samples from Core No. 2.

The amount of water held by the mud was determined, and correlated well with the mechanical analysis. The per cent moisture was calculated on the dry weight basis.

A study of cores from the lagoon bottom indicates that the cation exchange capacity varies from 0.5 milliequivalents per 100 gms material to zero, depending upon the depth at which samples are taken. The citrate ion was most effective in removing radioactive materials. This removal is attributed to the formation of soluble complexes with cerium and other radioactive elements.

A mechanical analysis shows that the amount of fine material decreases with depth and that the surface contains about 40% of material smaller than 2.0 microns.

[redacted]

The distribution of the mud, and its approximate thickness, is shown in figure 7. In the small central oval, approximately equivalent in area to that of a circle with a radius of 200 yd, the mud ranges from 1 to 8 ft in thickness. An average thickness of 50 in was assumed for this area. In the next zone, where the mud is 2 to 12 in in thickness, an average of 7 in was assumed. The outer zone, though much larger, has less than 2 in of mud; an average of 1 in was taken for this area.

These figures give volumes of 176,000 yd^3 of mud in the central area, 73,000 in the middle zone, and 68,000 in the outer one, or a total of 317,000 yd^3. The specific gravity of the mud in its wet state, as recovered (about 35% water), is 1.7. This gives a total wet weight of 455,000 tons. Since at least 10%, and probably more, of the mud resulting from the explosion has been disseminated throughout the lagoon beyond the mud area shown in figure 7, a value of half a million tons of radioactive mud probably is a safe estimate.

The question arises as to whether this impressive volume of mud was all originally present in the lagoon sediments, or whether some actually was produced due to pulverizing of coarser particles by the force of the explosion. Though this question cannot be answered positively until detailed size-distribution analyses of the sediment have been made, after return to the United States, preliminary inspection of the normal sediment suggests that sufficient sand, silt, and clay sizes exist with the Halimeda debris to account for most, if not all, of the mud and sand layers found.

The small bottom samples, bottom photographs, and fathometer records taken in Bikini Lagoon will be used to supplement the data collected last year. The bottom samples also will be available for radioactivity measurements, if desired.

Unfortunately, the three-day trip to the 700-fathom bank northwest of Bikini Atoll was not productive. LCI(L)-615 was not able to obtain sufficiently accurate location fixes, and during most of the time was not even on the bank. Only one sample was secured; a dredging (No. 24) in about 700 fathoms that brought up a small quantity of foraminiferal sand.

The other dredgings were quite successful, however, and furnish valuable information on the character of the outer reef slopes and of coral heads in the lagoon. Twenty-four hauls were made on the outer slopes of the reefs and five on two different coral heads. The locations of these hauls is shown in figure 6.

Only a few bottom samples on the outer reef and no dredgings were taken during OPERATION CROSSROADS. These few samples led to the erroneous conclusion that the surface of the outer reef, from 15 to 200 fathoms, is predominantly composed of a deep-water variety of Halimeda, and that below 200 fathoms the surface consists only of calcareous sand, decreasing in size with depth. (pp. F.3, F.4 of CROSSROADS report.)

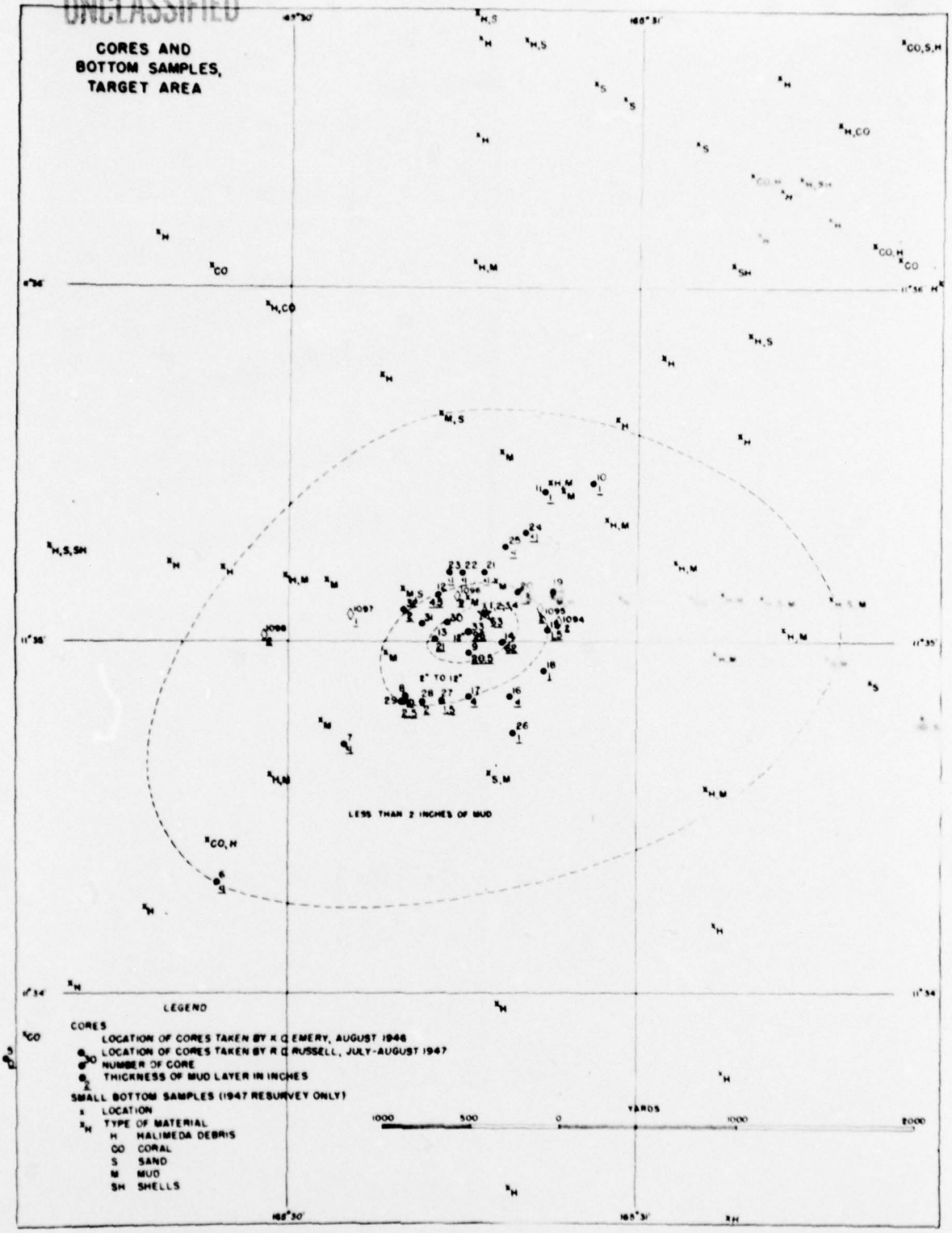


Figure 7. Cores and bottom samples, target area. ABOR Photo No. 5999-7.

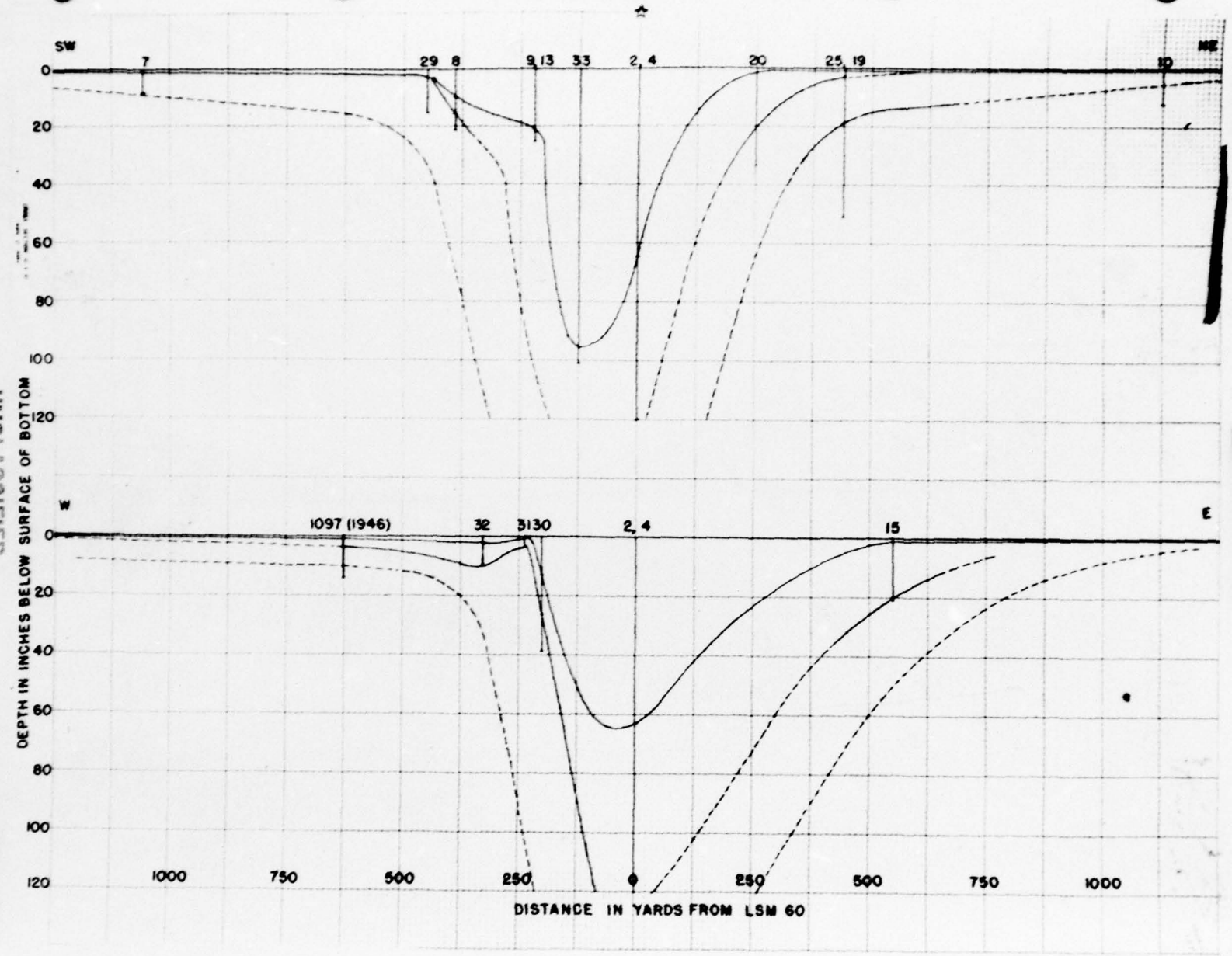


Figure 9. Cross sections of bottom in the target area. ABCR Photo No. 5999-8.

Area	Entire Organism	Bone	Gills	Skin	Muscle	
CHILTON 2,504		2.01(27)	5.74(32)	2.98(28)	1.58(29)	34
Trolling-Target Area		0.26(4)	1.15(4)	1.12(4)	0.97(4)	12
APOGON 2,000J		13.2 (1)	13.4 (1)	12.5 (2)	1.81(2)	21
NW Tip Bikini 2,407	0	0.51(5)	1.62(5)	0.08(4)	0.01(4)	0
NW of Bikini 2,307	1.16(4)	4.30(7)	6.53(7)	4.56(6)	2.49(7)	32
W of Bikini 2,207	1.49(9)	1.68(6)	3.62(5)	4.36(6)	0.53(6)	17
W of Bikini 2,107		1.91(7)	25.0 (7)	2.41(7)	1.00(7)	8
Coral head W of Bikini 2,007		4.68(9)	13.0 (9)	5.26(9)	.97(9)	61
Bikini-Amen 1,709	5.27(5)	21.9 (3)	9.91(3)	4.27(3)	4.10(3)	22
Coral head Bikini-Amen 1,709		19.1 (8)	17.5 (8)	9.65(8)	.95(8)	58
Trolling Bikini-Amen		1.00(9)	2.12(9)	1.55(9)	1.81(9)	27
Coral head near Amen Island 1,211		9.75(20)	2.17(20)	1.13(20)	1.43(20)	20
SE End of Amen Island 1,213	.47(1)	5.02(7)	8.42(7)	6.64(7)	4.80(7)	14
Uku 0,914	1.68(3)	1.93(9)	10.3 (9)	1.32(9)	0.91(9)	5
Namu-inner 9,514	.84(2)	0.40(11)	0.71(11)	2.64(11)	0.33(11)	2
Namu-outer 9,415	0 (1)	15.47(4)	1.24(4)	1.08(4)	0.35(4)	1
Boro Island-outside 8,700	0.63(9)	0.66(11)	1.00(11)	1.50(11)	1.12(11)	9
Boro Island-inside 8,799	0.42(3)	0.22(5)	2.17(5)	0.91(5)	0.93(5)	13
SW part of Atoll		3.63(17)	2.83(17)	2.60(17)	1.90(17)	4
Erik Island 0,390		0.34(13)	0.49(13)	0.81(13)	0.56(13)	2
Prayer Island 0,591		0.46(22)	1.07(4)	0.10(4)	1.29(4)	3
Coral head Airy-Biren Islands 0,891	3.02(1)	1.44(6)	1.06(9)	2.00(6)	1.59(10)	2
Arji Island 1,092	.43(2)	2.60(9)	2.43(9)	0.25(9)	1.16(9)	7
SE part of Atoll		0.76(20)	1.20(20)	1.48(20)	1.14(20)	4
Enyu Island-inner 2,792		0.34(14)	0.39(14)	0.24(14)	1.07(14)	9
Coral head N of Enyu 2,796	2.89(1)	1.16(24)	1.55(24)	1.43(24)	1.80(24)	10
Ion Island 2,797		2.33(12)	2.43(19)	0.35(12)	2.63(12)	19
Rokar Island-inner 2,798		1.26(9)	2.55(10)	2.21(9)	0.65(9)	11
Rokar Island-outer 2,899	1.29(1)	7.68(3)	5.72(6)	3.95(3)	1.08(3)	4
Average	1.58(42)	2.45(302)	4.16(302)	2.67(284)	1.49(276)	14

Table II. Average gross beta-gamma (c/min/gm) of wet fish tissues collected at Bikini (number of samples in parenthesis).

Gills	Skin	Muscle	Faeces	Liver	Spleen	Kidney	Gonads
5.74(32)	2.98(28)	1.58(29)	34.8 (36)	37.2 (43)	34.1 (20)	17.7 (15)	13.9 (5)
1.15(4)	1.12(4)	0.97(4)	12.2 (4)	14.7 (4)	11.9 (4)	6.99(4)	4.42(4)
3.4 (1)	12.5 (2)	1.81(2)	21.7 (2)	12.5 (3)			
1.62(5)	0.08(4)	0.01(4)	0.66(5)	11.0 (5)			
6.53(7)	4.56(6)	2.49(7)	32.57(7)	27.4 (7)	31.1 (1)	2.70(2)	9.12(2)
3.62(5)	4.36(6)	0.53(6)	17.3 (19)	19.5 (6)			
5.0 (7)	2.41(7)	1.00(7)	8.67(9)	29.1 (4)			
3.0 (9)	5.26(9)	.97(9)	61.1 (9)	64.7 (7)			
9.91(3)	4.27(3)	4.10(3)	22.1 (4)	26.8 (4)			24.7 (2)
7.5 (8)	9.65(8)	.95(8)	58.8 (9)	54.8 (9)	24.4 (1)	3.79(1)	6.11(2)
2.12(9)	1.55(9)	1.81(9)	27.1 (9)	25.1 (9)	17.7 (6)	12.2 (4)	4.87(2)
2.17(20)	1.13(20)	1.43(20)	20.0 (42)	26.0 (37)	32.6 (5)		
8.42(7)	6.64(7)	4.80(7)	14.7 (6)	16.4 (7)	24.7 (1)		12.3 (1)
0.3 (9)	1.32(9)	0.91(9)	5.28(9)	8.46(7)	0 (1)	10.0 (1)	
0.71(11)	2.64(11)	0.33(11)	2.86(15)	8.65(10)			4.21(1)
1.24(4)	1.08(4)	0.35(4)	1.24(17)	2.56(8)			
1.00(11)	1.50(11)	1.13(11)	9.55(22)	4.70(14)			
2.17(5)	0.91(5)	0.93(5)	13.05(6)	14.16(10)			
2.83(17)	2.60(17)	1.90(17)	4.09(17)	5.52(32)			
0.49(13)	0.81(13)	0.56(13)	2.66(13)	3.18(10)			1.36(1)
1.07(4)	0.10(4)	1.29(4)	3.25(24)	7.33(23)			
1.06(9)	2.00(6)	1.59(10)	2.92(23)	7.5 (12)	3.13(2)		
2.43(9)	0.25(9)	1.16(9)	7.73(16)	8.90(16)			
1.20(20)	1.48(20)	1.14(20)	4.33(20)	4.86(29)	8.35(17)	6.02(17)	1.89(5)
0.39(14)	0.24(14)	1.07(14)	9.97(19)	10.4 (20)		0 (1)	
1.55(24)	1.43(24)	1.80(24)	10.5 (31)	28.7 (28)	4.0 (1)	4.23(1)	
2.43(19)	0.35(12)	2.63(12)	19.4 (19)	28.4 (11)	68.3 (4)	34.2 (2)	
2.55(10)	2.21(9)	0.65(9)	11.7 (10)	26.2 (9)	17.7 (4)	22.8 (2)	
3.72(6)	3.95(3)	1.08(3)	4.35(6)	1.91(3)			
4.16(302)	2.67(284)	1.49(276)	14.53(428)	18.66(387)	23.51(67)	11.64(50)	8.16(25)

of wet fish tissues collected at Bikini Atoll during July-August 1947
number of samples in parenthesis).